

The Age of Gl879 and Fomalhaut

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ABSTRACT

We estimate here the age of one of the prototypes of the Beta Pic-like stars, Fomalhaut, based on the properties of its common proper motion companion Gl879. By combining constraints derived from the lithium abundance, rotational velocity, HR diagram position, and coronal activity we conclude that the age for Gl879, and hence the age for Fomalhaut, is 200 ± 100 Myr. This age estimate agrees quite well with the completely independent age estimate derived directly from isochrone-fitting to Fomalhaut’s position in an HR diagram, and thus confirms that circumstellar dust disks can persist in A stars for several hundred Myr.

Subject headings: star formation, planet formation, circumstellar disks

1. Introduction

One of the most interesting discoveries from the IRAS satellite was the detection of circumstellar dust disks around some nearby main sequence stars. The prototypes for this class of stars were Beta Pic, Vega and Fomalhaut (Gillett 1986), and these disks are often referred to as Beta Pic or Vega disks. As a result of their proximity and brightness, these three stars have been studied in most detail (Backman & Paresce 1993), including estimates of the mass, radial distribution and structure, dust-grain properties, etc. Subsequent to the discovery of the three prototype objects, other groups have searched the IRAS database and identified a large number of less prominent members of the class (Aumann 1985; Backman and Gillett 1987; Walker and Wolstencroft 1988). It has been estimated that 18% of the field A stars have circumstellar dust disks with $\tau \geq 2 \times 10^{-5}$ (Backman and Paresce 1993).

It is generally believed that these circumstellar dust disks are either the direct descendents of T Tauri disks or the secondary products of the planet formation process. Knowledge of the ages of Beta Pic stars is therefore one of the keys to the understanding of the formation and evolution of their disks. However, to date there is little firm information on the ages of these systems. No member of the class has yet been detected in an open cluster. Zuckerman et al. (1995) have estimated quite young ages (< 10 Myr) for several Beta Pic stars, but in most cases these estimates are based on relatively qualitative indicators. All three of the prototypes are A stars, and estimates from their post-ZAMS evolution give rough ages of 100, 200, and 400 Myr for Beta Pic, Fomalhaut and Vega, respectively, with uncertainties about 30% (Backman and Paresce 1993). This age estimate for Beta Pic differs considerably from the ~ 2 Myr proposed by Jura et al. (1993) based on the frequency of the A stars with $\tau \geq 10^{-3}$ among the Bright Star Catalog (Hoffleit and Jaschek, 1993), and with the ~ 10 Myr age estimated for it by Lanz et al (1995) based on a re-evaluation of its position in the HR diagram using an estimate of its surface gravity

provided by UV spectra. However, we note that the Lanz et al. age has very large error bars since the derived surface gravity differs at only the one sigma level from the ZAMS gravity, and thus an age of 100 Myr is also compatible with their data at the one sigma level.

As noted by Jura et al. (1993), the presence of a low mass companion to one prominent Beta Pic star - HR4796A - offers the chance to establish a relatively secure estimate for that star by determining a PMS isochrone-fitting age for the secondary. By doing this, Jura et al. derived an age of 3 Myr for HR4796A. Stauffer et al. (1995) obtained a high resolution spectrum to determine the lithium abundance of the secondary and also calibrated the isochrone-fitting age by use of photometry for low mass stars in open clusters and derived a revised age of 8 ± 2 Myr for HR4796.

In this paper, we will report a new age estimate for one of the three prototypes - Fomalhaut - based on analysis of the properties of its common-proper motion companion Gl879.

2. Observations and Data Reduction

Table 1 lists some properties of Fomalhaut (Gl881) and Gl879. The photometric data were selected from Bessel (1990), the activity indicators were obtained from Panagi & Mathioudakis (1993) and the IR fluxes from Oudmaijer et al. (1992) and Mathioudakis & Doyle (1993).

As can be seen, the agreement between either the radial velocities and apparent motion on the sky (Poveda et al. 1994) or the galactic velocity components (Anosova & Orlov 1991) indicates that both stars are, quite probably, physically associated, as was originally suggested by Gliese (1969). Since the possibility of a capture is extremely low, we conclude

that they must have been physically associated at birth and therefore, it is legitimate to estimate the age of Fomalhaut using constraints derived from its low mass companion.

A spectrum of Gl879 was obtained on May 21, 1995 with the echelle spectrograph on the Cerro Tololo Interamerican Observatory 4m telescope. We used the red, long camera and a Tektronix 2048×2048 CCD, a 31.6 l/mm grating and a 0.8 arcsec wide slit, yielding a resolving power of about $R \approx 50000$ at LiI 6708 Å, as measured with a Th–Ar comparison lamp. The total spectral range was $\lambda\lambda 5650\text{--}8050$ Å. Standard bias subtraction, flat-field correction and wavelength calibration was carried out using IRAF⁴. The final signal-to-noise ratio of the spectrum is ~ 130 .

Figure 1a shows the order which contains the LiI 6707.8 Å doublet. This feature is separable from the CN and FeI blend at 6707.4 Å due to the high resolution of the spectrograph and the low rotational velocity of Gl879 ($v \sin i \leq 4 \text{ km s}^{-1}$, estimated from the rotational period and the average radius for its spectral type). The equivalent widths measured by fitting two Gaussian curves to the spectrum are: $EW(\text{LiI}) = 33 \pm 2 \text{ mÅ}$ and $EW(\text{FeI} + \text{CN}) = 15 \pm 2 \text{ mÅ}$. We also measured $EW(\text{H}\alpha) = 754 \pm 16 \text{ mÅ}$ in absorption.

There is in the literature a previous measurement of the LiI equivalent width in Gl879. Favata et al. (1995) obtained a value of $EW(\text{LiI}) = 35 \text{ mÅ}$. Using Pallavicini et al.’s (1987) curves of growth and $T_{\text{eff}} = 4500 \text{ K}$, they determined a lithium abundance of $\log N(\text{Li}) = 0.4$ where $\log N(\text{Li}) = 12 + \log (N(\text{Li})/N(\text{H}))$.

We carried out a fine spectroscopic analysis to determine the effective temperature of Gl879. The equivalent widths of 55 clean unblended FeI lines were measured from our

⁴ IRAF is distributed by National Optical Astronomy Observatories, which is operated by the Association of Universities for Research in Astronomy, Inc., under contract to the National Science Foundation, USA

echelle spectrum. Solar gf-values were previously determined for these lines using solar equivalent widths measured from the Kurucz et al. (1984) solar atlas and the Kurucz solar atmospheric model (Kurucz 1992). The details and full list of gf-values will be provided in Balachandran, Carr and Lambert (1996). By requiring that the Fe abundance be constant for lines having different excitation potential, the spectroscopic temperature estimate is 4620 ± 150 K. The Fe abundance of Gl879 is $[\text{Fe}/\text{H}] = -0.11 \pm 0.02$. A spectral synthesis of the 6707.8 \AA region was performed with the LiI, FeI and CN features to obtain a Li abundance of $\log N(\text{Li}) = 0.6 \pm 0.15$ (see Fig. 1b).

In order to compare the Li abundance of Gl879 to that for the open cluster stars, we must first make certain that the conversions from the observables to T_{eff} and $\log N(\text{Li})$ used for Gl879 are compatible with those used for the cluster stars. Since a model atmosphere temperature analysis such as we have done for Gl879 is not possible for all of the cluster stars, we need to see how our temperatures and abundances would change if we used color-temperature conversions appropriate for the open cluster stars. As one test, we have derived a new T_{eff} estimate for Gl879 using the ad hoc "tuned" color-temperature conversion advocated by Stauffer et al. (1995) based on a comparison of the Pleiades single star V vs. $(V-I)_{\text{C}}$ main sequence to the D'Antona and Mazzitelli tracks. With this temperature $T_{\text{eff}} = 4440$ K and Soderblom et al's (1993b) curves of growth, we obtain $\log N(\text{Li}) = 0.5$. In order to check the uncertainties introduced by the color-temperature conversion, as a second test we have estimated Gl879's effective temperature using the $(B-V) - T_{\text{eff}}$ calibration adopted by Thorburn et al. (1993). This is exactly the temperature scale we use in Section 3 for the open cluster stars. With this scale, we derive $T_{\text{eff}} = 4500$ K, which then yields $\log N(\text{Li}) = 0.6$ with Soderblom et al.'s (1993b) curves of growth. These results do not differ significantly from our rigorous temperature determinations, so we adopt $T_{\text{eff}} = 4500$ K, $\log N(\text{Li}) = 0.6$ as a suitable compromise.

3. Discussion

In the following discussion, we will attempt to age-date Gl879, and therefore Fomalhaut’s age, by comparison of its properties to those of stars in several open clusters. For this to provide an age for Gl879, we must adopt ages for the open clusters; there is uncertainty in this step, however, as there is often disagreement over the exact age to attribute to a given cluster. We have attempted to adopt a consistent age scale for the set of clusters to which we will compare our Gl879 data after having made a survey of the relevant literature (Paternaude 1978; Giannuzzi 1979; Mermilliod 1981; Meynet et al. 1993; Soderblom & Mayor 1993; Jones and Prosser 1996). For definiteness, the age scale we adopt is: Pleiades - 85 Myr; M34 - 200 Myr; Ursa Major - 300 Myr; Hyades - 700 Myr. Our derived age for Gl879 is directly tied to this age scale; if future efforts provide better ages for these clusters, then our age estimate for Gl879 should be adjusted appropriately.

3.1. The Age of Gl879 as Estimated from Its Lithium Abundance

Figure 2a shows the lithium abundance against the effective temperature for the Hyades (filled circles for single stars and wide binaries and filled triangles for tidally-locked binaries) and Pleiades (open circles) open clusters. The original lithium equivalent widths for the Hyades were selected from Boesgaard & Tripicco (1986), Rebolo & Beckman (1988), Soderblom et al. (1990), Thorburn et al. (1993) and Barrado y Navascués & Stauffer (1996). The abundances of Pleiades stars were taken from Pilachowski et al. (1987), Soderblom et al. (1993b) and García-López et al. (1994). We estimated the lithium abundances using the Thorburn et al. (1993) temperature scale and curves of growth used for Gl879. There is some evidence that tidally-locked binaries may retain a larger fraction of their initial lithium abundance perhaps due to the absence of rotational spin-down (Zahn 1994). Comparing Gl879 with the *single* Hyades stars, it is immediately clear that Gl879

must be considerably younger than the Hyades. Based on this figure alone, Gl879 could be as young as the Pleiades, since it falls along the lower envelope of lithium abundances for Pleiades stars of the same color.

Although the data are sparse, clusters between the ages of the Pleiades and the Hyades, the UMa Moving group at 300 My and M34 at 200 Myr, provide further constraint. Figure 2b shows the available lithium data in the UMa Moving Group (filled circles, Soderblom et al. 1993a) and M34 cluster (open circles, Soderblom 1995). Gl879 appears to fall along the lower envelope of M34. The overlap between lithium abundances in M34 and the Pleiades and the scatter in abundances at a given T_{eff} preclude any firm estimate of the lower age limit for Gl879 from the lithium data. (A stronger constraint on the lower age limit for Gl879 will be obtained from X-ray fluxes in Section 3.2.) Comparison of the UMa and M34 abundances shows that UMa abundances are consistently lower than M34 both around 6000 K and 5000 K. A lithium depletion curve (age = 300 Myr, initial rotational velocity equal to 10 km s^{-1}) from Chaboyer (1993) is plotted to indicate the general shape of lithium depletion as a function of T_{eff} . Although there is only a single upper limit in the UMa data at the temperature of Gl879, we extrapolate the available data to arrive at the reasonable speculation that UMa abundances will probably lie below Gl879 at 4500 K. Given this hypothesis, we conclude that the age of Gl879 is less than 300 Myr.

3.2. The Age from the X-ray Activity

The rotational velocities of low mass stars decrease with time due to angular momentum loss from stellar winds. However, particularly for stars older than about 100 Myr, these rotational velocities become difficult to measure because they drop below the resolution limit of standard high-resolution spectrographs. The chromospheric and coronal activity of low mass stars also decrease with increasing age, presumably as a direct result of

the decreasing rotational velocities, and thus it is possible to also use measures of these properties as age indicators. In some cases, these surrogate rotational velocity indicators provide better constraints than the rotational velocities themselves because it is easier to measure the surrogate indicators than to measure rotation directly.

Figure 3a shows Log L_x versus (B–V) for Pleiades members (Stauffer et al. 1994) and for Gl879 (Panagi and Mathiotakis 1993), and Figure 3b shows similar data for the Hyades (Stern et al. 1995). Filled circles represent actual values, and open triangles represent upper limits; the cross indicates the value for Gl879. The most important conclusion to be drawn from these plots is that Gl879 must be *significantly older* than the Pleiades since its coronal activity - and thus presumably its rotational velocity - is much less than that for any Pleiades stars of the same color. The X-ray data for the Hyades do not provide a very useful constraint - Gl879 could be as old or even slightly older than the Hyades, because there is a large spread in the X-ray emission of Hyades stars at a given mass. We thus conclude that the X-ray data indicates that the age of Gl879 is significantly larger than 85 Myr.

3.3. The Age as Estimated from Rotation

As mentioned in the previous subsection, the rotation of solar-type main sequence stars decreases with increasing age, so that the rotational period can also be used as an age indicator. Actual rotational periods versus the (B–V) color indices are plotted in Fig. 4. The data were selected from Prosser et al. (1993, 1995) –Pleiades, open circles– and Radick et al. (1987) –Hyades, filled circles. Rotational periods are available only for a small fraction of the stars in each cluster. For the Hyades, this is not a problem because in the relevant color range all Hyades members are likely to follow a very tight period-mass relation (Duncan et al. 1984); for the Pleiades however, the selection effects are important

since it is much easier to derive rotational periods for rapid rotators than for slow rotators. Based on the vsini data available in the literature (see Stauffer et al. 1994 and references therein), only one quarter to one third of the Pleiades K dwarfs should have periods less than one day whereas the majority of them have $\text{vsini} < 10 \text{ km s}^{-1}$ and thus should have periods of 5 days or longer. Therefore, the lack of Pleiades members with $P > 4$ days and $(B-V) > 1.1$ in Figure 4 is entirely due to selection effects in the photometric monitoring programs. Thus, we interpret Figure 4 as indicating that Gl879 is very probably younger than the Hyades and older than the Pleiades, though the sparseness of the rotational velocity database (particularly the lack of period determinations for the slowly rotating Pleiades K dwarfs) limits our confidence in these limits. Efforts currently in progress to determine rotation periods of Pleiades and Hyades K dwarfs (Krishnamurthi et al. 1995; Allain and Bouvier 1995) should allow an improved estimate in the near future.

3.4. The Age as Derived from the Color–Magnitude Diagram

We have tried to estimate the age of Gl879 using its position on the $M_V-(V-I)_C$ plane, following Stauffer et al. (1995). Figure 5 shows the D’Antona & Mazzitelli (1994) isochrones for 3, 10, 35, 70 Myr and the Zero Age Main Sequence (ZAMS). The Pleiades data are shown as open circles. Based on this diagram alone, Gl879 would be assigned an age slightly older than 35 Myr. However, for a variety of reasons, we do not believe that Gl879 can be this young. Plausible errors in the observational properties can shift Gl879 to much older ages in this diagram. For example, if Gl879 was really at the distance of Gl881 (allowed within the two sigma errors), then Gl879 would be 0.4 magnitudes fainter in Figure 5 and would be essentially on the ZAMS and thus compatible with any age up to several Gyr. The position of Gl879 could also be shifted in the diagram due to spot-related photometric variability. For these reasons (errors in the observational

properties, spot-related photometric variability), we believe that, in this particular case, this diagram is not accurate enough for our purposes.

3.5. Summary of Age Constraints for Gl879

Table 2 summarizes our attempts to constrain the age of Gl879 (and hence to constrain the age of Fomalhaut). Lithium provides the best constraint on the maximum age of the system, indicating that Gl879 is less than about 300 Myr old. Coronal activity provides the best constraint on how young the two stars could be - indicating that they are significantly older than 85 Myr. Thus, our age estimate for Gl879 and Fomalhaut is 200 ± 100 Myr.

4. Conclusions

Based on different properties of the late spectral type companion of Fomalhaut, we have estimated the age of this Beta Pic star, yielding a value of 200 ± 100 Myr. This age is totally compatible with, and independent of, the age derived for the primary from its position in the CM diagram and thus adds confidence to post-ZAMS CM diagram ages derived for the other Beta Pic prototypes by Backman and Paresce. The comparison between the ages and IR excesses between Fomalhaut and HR4796A suggests that the disks evolve with time, as expected.

As an aside, we note that Anosova & Orlov (1991) have suggested that Gl879 and Gl881 may be part of a moving group including the multiple system ADS6175, which contains three spectroscopic binaries (Castor A, Castor B and YY Gem). This moving group has been proposed to contain about 18 stars, having spectral types between A1V and M6Ve. The positions of several members of the group in $M_V - (V-R)_C$ and $M_V - (B-V)$ diagrams agree with our age assignment for Gl879.

If this moving group is real and Fomalhaut and Gl879 are part of it, all these stars would have the age estimated for Gl879. YY Gem, a very well known eclipsing binary, is one of these stars. It is one of the two systems of M dwarfs with accurate measurements of radii and temperatures. Depending on the exact age which is assigned, YY Gem may be a pre-main sequence star close to the ZAMS. If it is indeed still contracting to the ZAMS, then the calibrations of theoretical models under the assumption that it is a MS stars would be slightly in error. This points out the need to continue to search for other appropriate dM binaries from which masses and radii can be derived.

Recently, Chabrier & Baraffe (1995) have estimated the age of YY Gem by fitting isochrones which were computed using a new equation of state and new opacities. They obtained an age of 100 Myr and a solar-like metallicity, which implies that the components of YY Gem should still be slightly above the ZAMS. Since the age uncertainty for YY Gem due to errors in its parallax and effective temperature should not be larger than about 50 Myr, this would suggest that Gl879 has a younger age than we have derived if YY Gem and Gl879 are indeed coeval. Since this is a more indirect way to estimate the age of Gl879 than the methods we have used, and since it is possible that the Castor group is not physically associated with Gl879 and Fomalhaut, we have chosen not to modify our current age estimate for Fomalhaut. However, this subject should be readdressed if better parallaxes, proper motions and metallicities for Gl879 and YY Gem can be obtained to assess better the reality of their group membership.

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Table 1: Data for the physical pair Gl879 + Gl881 (Fomalhaut)

	Gl879	Gl881	Reference
Sp. Type	K5 Ve	A3 V	a
V	6.46–6.48	1.16	b
(B-V)	1.10	0.08–0.09	c
(V-R) _C	0.660	0.055	c
(R-I) _C	0.545	0.025	c
(V-I) _C	1.205	0.080	c
M _v	7.02	2.09	
Parallax	0.128±0.014	0.154±0.008	a
U (kms ⁻¹)	-4	-5	d
V (kms ⁻¹)	-8	-7	d
W (kms ⁻¹)	-4	-10	d
μ (″/yr)	0.360	0.372	e
θ (degree)	114.6	115.6	e
γ (kms ⁻¹)	9.0	6.1-6.5	e
P _{rot} (d)	10.30	~1	f
Log L _x (ergs ⁻¹)	28.3	–	c

a SIMBAD database. b Oudmaijer et al. 1992. c Panagi & Mathioudakis 1993. d Anosova & Orlov 1991. e Poveda et al. 1994. f Busko & Torres 1978.

Table 2: Different estimations for the age of Gl879.

Method	Age (Myr)	Quality
Lithium	<300	Good
Activity	>85,<600	Good
Rotation	>85,<600	Fair
CM diagram	>30	Poor
Final	200±100	–

REFERENCES

- Allain, S., Bouvier, J., 1995. In “9th Cambridge Workshop in Cool Stars, Stellar Systems and the Sun”. In press
- Anosova, J. P., Orlov, V. V., 1991, A&A 252, 123
- Aumann, H. H., 1985, PASP 97, 885.
- Backman, D. E., Gillett, F. C., 1987, “5th Cambridge Workshop in Cool Stars, Stellar Systems and the Sun”, eds. J.L. Linsky & R.E. Stencel. Lecture notes in Physics 291, 340
- Backman D. E., Paresce, F., 1993, in “Protostars and Planets III”. Eds. E. H.Levy, J. I. Lunine, M. S. Matthews. Tucson, University of Arizona Press
- Balachandran, S. C., Carr, J. S., Lambert, D. L., 1996, in preparation.
- Barrado y Navascués, D., Stauffer, J. R., 1996, A&A 310, 879
- Bessel, M. S., 1990, A&AS 83, 357
- Boesgaard, A. M., and Tripicco, M., 1986, ApJS 302, L49
- Boesgaard, A. M., Budge, K. G., Ramsay, M. E., 1988, ApJ 327, 389
- Busko, I. C., Torres, C. A. O., 1978 A&A 64, 153
- Chaboyer, B., 1993. Ph.D. Thesis. Yale Univ.
- Chabrier, G., Baraffe, I., 1995, ApJ 451, L29
- D’Antona, F., Mazzitelli, I., 1994, ApJS 90, 467

- Duncan, D. K. Frazer, J. Lanning, H. H., Baliunas, S. L. Noyes, R. W., Vaughan, A. H., 1984, PASP 96, 714
- Favata, F., Micela, G., Sciortino, S., 1995a, A&A 297, L1
- García López, R. J., Rebolo, R., Martín, E. L., 1994 A&A 282, 518
- Giannuzzi, M. A., 1979, A&A 77, 214
- Gillett, F. C., 1986, in “Light on dark matter: First IRAS conference”, Dordrech, Reidel Publishing Co.
- Gliese, W., 1969, Weroeff. Astron. Rechen-Inst., 22, 1
- Hoffleit, D., Jaschek, C., 1993. The Bright Star Catalog, New Haven, Yale Univ. Obs.
- Jones, B. F., Prosser, C. F., 1996, AJ 111, 1193
- Jura, M., Zuckerman, B., Becklin, E. E., Smith, R. C., 1993, ApJ 418, L37
- Krishnamurthi, A. E. A., Terndrup, D. M., Pinsonneault, M. H., Sellgren, K., Stauffer, J. R., 1995, BAAS 27, 1437
- Kurucz R. L., 1992, Rev. Mex. Astron. Astrof. 23, 181
- Kurucz R. L., et al. 1984, National Solar Observatory Atlas, vol. 1
- Lanz, T., Heap, S. and Hubeny, I., 1995, ApJ 447, L41
- Mathioudakis, M., Doyle, J. G., 1993, A&A 280, 181
- Mermilliod, J.-C., 1981, A&A 97, 235
- Meynet, G., Mermilliod, J.-C., Maeder, A., 1993, A&AS 98, 477

- Oudmaijer, R. D., van der Veen, W. E. C. J., Waters, L. B. F. M., Trams, N. R., Waelkens, C., Engelsman, E., 1992, A&AS 96, 625
- Pallavicini, R., Cerruti-Sola, M., Duncan, D. K., 1987, A&A 174, 116
- Panagi, P. M., Mathioudakis, M., 1993, A&AS 100, 343
- Patenaude, M., 1978, A&A 66, 225
- Pilachowski, C. A., Booth, J., and Hobbs, L. M., 1987 PASP, 99, 1288
- Poveda, A., Herrera, M. A., Allen, C., Cordero, G., Lavalley, C., 1994, Rev. Mex. de Astron. 28, 43
- Prosser, C. F., Shetrone, M. D., Marilli, E., Catalano, S., Willians, S. D., Backman, D. E., Laaksonen, B. D., Adige, V., Marschall, I. A., Stauffer, J. R., 1993 PASP 105, 1407
- Prosser, C.F., Shetrone, M. D., Dasgupta, A., Backman, D. E., Laaksonen, B. D., Baker, S. W., Marschall, L. A., Whitney, B. A., Kuijken, K., Stauffer, J. R., 1995 PASP 107, 221
- Radick, R. R., Thomson, D. T., Lockwood, G. W., Duncan, D. K., Bagget, W. E., 1987, ApJ 321, 459
- Rebolo, R., Beckman, J. E., 1988, A&A 201, 267
- Schaeller, G., Schaerer, D., Meynet, G., Maeder, A., 1992, A&AS 96, 269
- Schaerer, D., Meynet, G., Maeder, A., Schaller, G., 1993a, A&AS 98, 523
- Schaerer, D., Charbonnel, C., Meynet, G., Maeder, A., Schaller, G., 1993b, A&AS 102, 339
- Soderblom, D. R., Oey, M. S., Johnson, D. R. H., Stone, R. P. S., 1990, AJ 99, 595
- Soderblom, D. R., Mayor, M., 1993 AJ 105, 2299

- Soderblom, D. R., Pilachowski, C. A., Fédele, S. B, Jones, B. F., 1993a, AJ 105, 2299
- Soderblom, D. R., Jones, B. F., Balachandran, S., Stauffer, J. R., Duncan, D. K., Fédele, S. B., Hudon, J. D., 1993b AJ 106, 105
- Soderblom, D. R., 1995, private communication
- Stauffer, J. R., Hartmann, L., Barrado y Navascués, D., 1995, ApJ, 454, 910
- Stauffer, J. R., Caillault, J. P., Gagne, M., Prosser, C., Hartmann, L. M., 1994, ApJS 91, 625
- Stern, R. A., Schmitt, J. H. M. N, Kahabka, P. T., 1995 ApJ 448, 683
- Thorburn, J. A., Hobbs, L. M., Deliyannis, C. P., Pinsonneault, M. H., 1993, ApJ 415, 150
- Walter, H. J., Wolstencroft, R. D., 1988, PASP 100, 1509
- Zahn, J–P., 1994, A&A 288, 829
- Zuckerman, B., Forveille, T., Kastner, J. H., 1995, Nature 373, 494

Figure Captions

Fig. 1.— **a** Spectrum of Gl879. As can be seen, FeI6707.4 Å and LiI6707.8 Å are resolved, due to the high resolution and to the small *vsini* value. **b** Detail around LiI6707.8 Å. The original spectrum is shown as a solid line whereas the synthetical fit appears as a dotted line.

Fig. 2.— Li abundance against effective temperature. **a** Hyades (filled circles represent single stars and normal binaries and filled triangles represent tidally-locked binaries) and Pleiades (open circles) data. **b** UMa Group (filled circles) and M34 cluster (open circles). A lithium depletion isochrone by Chaboyer (1993), computed with an initial rotational velocity equal to 10 km s^{-1} and an age of 300 Myr, is shown.

Fig. 3.— Luminosity in X rays -in logarithm- against the color index (B–V). Filled circles represent actual values, whereas open triangles are upper limits. **a** Pleiades data. **b** Hyades data.

Fig. 4.— Comparison between the rotational periods of Gl879, Hyades stars (filled circles) and Pleiades members (open circles).

Fig. 5.— Color–Magnitude Diagram for Gl879, HR4796B -physical companion of another Beta Pic analog- and the Pleiades (open circles). The isochrones by D’Antona and Mazzitelli (1994), for ages 3, 10, 35, 70 Myr and the ZAMS, from top to bottom, are also included.















